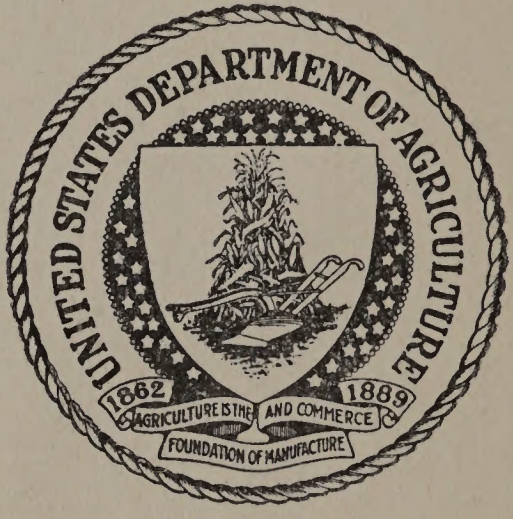
UNITED STATES DEPARTMENT OF AGRICULTURE

FOREST SERVICE

GIFFORD PINCHOT, Forester

INSTRUCTIONS FOR MAKING FOREST SURVEYS AND MAPS

1907



Issued July —, 1907.

U. S. DEPARTMENT OF AGRICULTURE,
FOREST SERVICE.
GIFFORD PINCHOT, Forester.

INSTRUCTIONS FOR MAKING FOREST SURVEYS AND MAPS.

1907.

Superseded by instructions of 1910

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1907.

CONTENTS.

ILLUSTRATIONS.

INSTRUCTIONS FOR MAKING FOREST SURVEYS AND MAPS.

These instructions are issued to members of the Forest Service in order that forest surveys and maps may be as nearly uniform as practicable. They do not include directions for the use of instruments of great precision, and the tables are prepared only to such accuracy as is attained in careful timber cruising or in surveying with the magnetic compass. This is $\frac{1}{4}°$ or 15′ of arc.[a]

SURVEYS.

Forest surveys are made for two purposes—to locate and mark lines or boundaries upon the ground, or to furnish data for the preparation of maps.

The correctness of a survey depends upon the excel-

[a] The "diurnal" or daily change of a magnetic needle, which is one of the variations for which allowance is made in precise surveying, amounts to 10′ or 15′, and the influence of magnetic storms upon the needle is frequently unsuspected at the time a survey is made.

Clinometers and clinometer-compasses, by which the degree of a slope or a vertical angle may be measured, are generally read only to the nearest $\frac{1}{2}°$ or $\frac{1}{4}°$.

Members of the Forest Service who are using solars, transits, levels, etc., have received training and experience in the care and use of such instruments, and can execute the necessary surveys of precision.

lence of the instruments in use and the skill of the surveyor and his party. The principal instrument is the magnetic compass, which, although of very simple construction, will be absolutely misleading to anyone who uses it without understanding. Suppose, for instance, a good compass, manufactured and adjusted in some eastern factory or in Europe, should be taken to the Pacific coast. It would undoubtedly indicate the direction of the magnetic currents at any time and place that it might be used, but its needle would not point north and south and probably would not hang level on the center pivot. This latter defect is quickly remedied by moving a little sliding weight, which should be on the south end of the needle.

MAGNETIC NEEDLE.

It is unfortunate that all makers of surveying instruments do not have a uniform method of designating the north or south ends of compass needles, but that the surveyor must learn and remember whether the blue or white or the weighted or cross-barred end of the needle is the one which points northward. In good weather, when the sun shines or where distant features of the landscape are in constant view, there is little chance of error by reading the wrong end of the needle, but there are many conditions under which the compass alone must be the guide.

VARIATION.

It will be seen by the map (fig. 1) that only along one line in the United States does the needle point due north. This line is not stationary, but has a slow

nstructions for Forest Surveys and Maps, Forest Service, U. S. Department of Agriculture.

FIG. 1.—LINES OF EQUAL MAGNETIC VARIATION IN THE UNITED STATES.

West of the heavy lines the variation is east of true north. East of the heavy lines the variation is west of true north.

movement westward. At all other points in the United States the north end of the needle is deflected toward the "line of no variation." In the North Atlantic States the variation of the north end of the needle is to the west, and a surveyor at Augusta, Me., would enter in his field notes "variation 16° west." At Portland, Oreg., the entry would be "variation 21½° east."

If a survey is to be made in a region which has not been subdivided by Government land surveys or where the variation of the needle is not known, then the surveyor must do one of two things. He should, if possible, find the variation by observing the Pole Star, of which approximate bearings are given (Table 1) at 9 p. m. during the year. If this can not be done, a variation may be assumed after examination of fig. 1, and this assumed variation should be entered in the field notes and shown on the map, with the date when the map is prepared.

POLARIS.

The Pole Star is not exactly above the North Pole of the earth, but its bearing is due north twice a day, and an observation of it at one of these times will give a true meridian. A double star in the bend of the handle of the Big Dipper is either above or below the Pole Star at these times. (See fig. 2, which illustrates these two positions.) At all other hours the Pole Star has a bearing either east or west of true north. It is most convenient to take a sight on Polaris at 9 p. m., and for this reason the accompanying table was prepared. The sight having been taken, it will be easy to turn the compass to true north and ascertain the variation.

FIG. 2.—Position of the Big Dipper above or below the Pole Star when the Pole Star is due north.

TABLE 1.—*Bearing of Polaris, east or west of true north, at 9 p. m. at different latitudes in the United States. This table is approximate until 1910.*

Date.		Latitude.											
		26°.	28°.	30°.	32°.	34°.	36°.	38°.	40°.	42°.	44°.	46°.	48°.
Jan.	1	¾° W.	¾° W.	¾° W.	¾° W.	¾° W.	¾° W.	¾° W.	1 ° W.	1 ° W.	1 ° W.	1 ° W.	1 ° W.
	15	1	1	1	1	1	1	1¼	1¼	1¼	1¼	1¼	1¼
Feb.	1	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1½	1½	1½	1½	1½
	15	1¼	1¼	1¼	1¼	1½	1½	1½	1½	1½	1¾	1¾	1¾
Mar.	1	1¼	1¼	1½	1½	1½	1½	1½	1½	1½	1¾	1¾	1¾
	15	1¼	1¼	1¼	1¼	1¼	1½	1½	1½	1½	1½	1½	1¾
Apr.	1	1	1	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1½	1½
	15	1	1	1	1	1	1	1	1	1	1	1¼	1¼
May	1	½	½	½	¾	¾	¾	¾	¾	¾	¾	¾	¾
	15	¼° W.	¼° W.	¼° W.	¼° W.	¼° W.	¼° W.	¼° W.	¼° W.	¼° W.	¼° W.	½° W.	½° W.
June	1	North . .											North.
	15	½° E.	½° E.	½° E.	½° E.	½° E.	½° E.	½° E.	½° E.	½° E.	½° E.	½° E.	½° E.
July	1	¾	¾	¾	¾	¾	¾	¾	¾	¾	¾	1	1
	15	1	1	1	1	1	1	1	1	1¼	1¼	1¼	1¼
Aug.	1	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1½	1½	1½	1½
	15	1¼	1¼	1¼	1¼	1½	1½	1½	1½	1½	1½	1¾	1¾
Sept.	1	1¼	1¼	1¼	1½	1½	1½	1½	1½	1½	1¾	1¾	1¾
	15	1¼	1¼	1¼	1¼	1¼	1½	1½	1½	1½	1½	1¾	1¾
Oct.	1	1	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1½	1½	1½
	15	1	1	1	1	1	1	1	1	1	1¼	1¼	1¼
Nov.	1	½	½	½	¾	¾	¾	¾	¾	¾	¾	¾	¾
	15	¼° E.	¼° E.	¼° E.	¼° E.	¼° E.	¼° E.	¼° E.	¼° E.	¼° E.	¼° E.	½° E.	½° E.
Dec.	1	North. .											North.
	15	½° W.	½° W.	½° W.	½° W.	½° W.	½° W.	½° W.	½° W.	½° W.	½° W.	½° W.	½° W.

RESURVEYS.

When a survey is to be made in a township which has been subdivided, or when the lines of old survey boundaries are to be retraced, the prime object is to *follow* all of the legal lines and to check up on all of the legal corners. For this purpose the surveyor should know:

(1) The date when the original survey was made.

(2) The variation used.

(3) The change in variation, increase or decrease, since the original survey was made.

In any western State this information may be obtained from the surveyor-general, and usually from the county surveyor of the county in which the survey is to be made. In any event the new variation, as determined by the resurvey, should be entered in the field notes for future reference.

Do not allow the needle to be deflected, while being read, by an ax, jackknife, pencil tip, the metal band of a hat, or other metal. The compass should not be kept near iron, even when not in use, as the needle is likely to be demagnetized.

TRAVERSE.

When a survey is run along a road or stream, or follows the crest of a divide, the line "meanders" and consists of a number of short courses and distances. The courses are read from the north end of the needle and platted on the map with a protractor. Whenever the actual change in latitude or departure (longitude) is desired, it may be computed with the traverse table.

In platting with the protractor care should be used that all the angles are set off from the same meridian, otherwise the errors will accumulate. The angles of all courses in surveying are measured from the north and south cardinals toward the east or west, and they should be platted the same. The figures on some protractors are misleading in this respect.

TABLE 2.—*Traverse.*

Course.	Dist. 1.		Dist. 2.		Dist. 3.		Dist. 4.		Dist. 5.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
° ′											° ′
0 15	1.0000	0.0044	2.0000	0.0087	3.0000	0.0131	4.0000	0.0175	5.0000	0.0218	89 45
30	0000	0087	1.9999	0175	2.9999	0262	3.9998	0349	4.9998	0436	30
45	0.9999	0131	9998	0262	9997	0393	9997	0524	9996	0654	15
1 0	9998	0175	9997	0349	9995	0524	9994	0698	9992	0873	89 0
15	9998	0218	9995	0436	9993	0654	9990	0873	9988	1091	45
30	9997	0262	9993	0524	9990	0785	9986	1047	9983	1309	30
45	9995	0305	9991	0611	9986	0916	9981	1222	9977	1527	15
2 0	9994	0349	9988	0698	9982	1047	9976	1396	9970	1745	88 0
15	9992	0393	9985	0785	9977	1178	9969	1570	9961	1963	45
30	9990	0436	9981	0872	9971	1309	9962	1745	9952	2181	30
45	0.9988	0.0480	1.9977	0.0960	2.9965	0.1439	3.9954	0.1919	4.9942	0.2399	15
3 0	9986	0523	9973	1047	9959	1570	9945	2093	9931	2617	87 0
15	9984	0567	9968	1134	9952	1701	9936	2268	9920	2835	45
30	9981	0610	9963	1221	9944	1831	9925	2442	9907	3052	30
45	9979	0654	9957	1308	9936	1962	9914	2616	9893	3270	15
4 0	9976	0698	9951	1395	9927	2093	9903	2790	9878	3488	86 0
15	9973	0741	9945	1482	9918	2223	9890	2964	9863	3705	45
30	9969	0785	9938	1569	9908	2354	9877	3138	9846	3923	30
45	9966	0828	9931	1656	9897	2484	9863	3312	9828	4140	15
5 0	9962	0872	9924	1743	9886	2615	9848	3486	9819	4358	85 0
15	0.9958	0.0915	1.9916	0.1830	2.9874	0.2745	3.9832	0.3660	4.9 90	0.4575	45
30	9954	0958	9908	1917	9862	2875	9816	3834	9770	4792	30
45	9950	1002	9899	2004	9849	3006	9799	4008	9748	5009	15
6 0	9945	1045	9890	2091	9836	3136	9781	4181	9726	5226	84 0
15	9941	1089	9881	2177	9822	3266	9762	4355	9703	5443	45
30	9936	1132	9871	2264	9807	3396	9743	4528	9679	5660	30
45	9931	1175	9861	2351	9792	3526	9723	4701	9653	5877	15
7 0	9925	1219	9851	2437	9776	3656	9702	4875	9627	6093	83 0
15	9920	1262	9840	2524	9760	3786	9680	5048	9600	6310	45
30	9914	1305	9829	2611	9743	3916	9658	5221	9572	6526	30
45	0.9909	0.1349	1.9817	0.2697	2.9726	0.4046	3.9635	0.5394	4.9543	0.6743	15
8 0	9903	1392	9805	2783	9708	4175	9611	5567	9513	6959	82 0
15	9897	1435	9793	2870	9690	4305	9586	5740	9483	7175	45
30	9890	1478	9780	2956	9670	4434	9561	5912	9451	7390	30
45	9884	1521	9767	3042	9651	4564	9534	6085	9418	7606	15
9 0	9877	1564	9754	3129	9631	4693	9508	6257	9384	7822	81 0
15	9870	1607	9740	3215	9610	4822	9480	6430	9350	8037	45
30	9863	1650	9726	3301	9589	4951	9451	6602	9314	8252	30
45	9856	1693	9711	3387	9567	5080	9422	6774	9278	8467	15
10 0	9848	1736	9696	3473	9544	5209	9392	6946	9240	8682	80 0
15	0.9840	0.1779	1.9681	0.3559	2.9521	0.5338	3.9362	0.7118	4.9202	0.8897	45
30	9833	1822	9665	3645	9498	5467	9330	7289	9163	9112	30
45	9825	1865	9649	3730	9474	5596	9298	7461	9123	9326	15
11 0	9816	1908	9633	3816	9449	5724	9265	7632	9081	9540	79 0
15	9808	1951	9616	3902	9424	5853	9231	7804	9039	9755	45
30	9799	1994	9598	3987	9398	5981	9197	7975	8996	9968	30
45	9790	2036	9581	4073	9371	6109	9162	8146	8952	1.0182	15
12 0	9781	2079	9563	4158	9344	6237	9126	8316	8907	0396	78 0
15	9772	2122	9545	4244	9317	6365	9089	8487	8862	0609	45
30	9763	2164	9526	4329	9289	6493	9052	8658	8815	0822	30
45	0.9753	0.2207	1.9507	0.4414	2.9260	0.6621	3.9014	0.8828	4.8767	1.1035	15
13 0	9744	2250	9487	4499	9231	6749	8975	8998	8719	1248	77 0
15	9734	2292	9468	4584	9201	6876	8935	9168	8669	1460	45
30	9724	2334	9447	4669	9171	7003	8895	9338	8618	1672	30
45	9713	2377	9427	4754	9140	7131	8854	9507	8567	1884	15
14 0	9703	2419	9406	4838	9109	7258	8812	9677	8515	2096	76 0
15	9692	2462	9385	4923	9077	7385	8769	9846	8462	2308	45
30	9681	2504	9363	5008	9044	7511	8726	1.0015	8407	2519	30
45	9670	2546	9341	5092	9011	7638	8682	0184	8352	2730	15
15 0	9659	2588	9319	5176	8978	7765	8637	0353	8296	2941	75 0
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Course.
	Dist. 1.		Dist. 2.		Dist. 3.		Dist. 4.		Dist. 5.		

TABLE 2.—*Traverse*—Continued.

Course.	Dist. 6.		Dist. 7.		Dist. 8.		Dist. 9.		Dist. 10.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
° ′											° ′
0 15	5.9999	0.0262	6.9999	0.0305	7.9999	0.0349	8.9999	0.0393	9.9999	0.0436	89 45
30	9998	0524	9997	0611	9997	0698	9997	0785	9996	0873	30
45	9995	0785	9994	0916	9993	1047	9992	1178	9991	1309	15
1 0	9991	1047	9989	1222	9988	1396	9986	1571	9985	1745	89 0
15	9986	1309	9983	1527	9981	1745	9979	1963	9976	2181	45
30	9979	1571	9976	1832	9973	2094	9969	2356	9966	2618	30
45	9972	1832	9967	2138	9963	2443	9958	2748	9953	3054	15
2 0	9963	2094	9957	2443	9951	2792	9945	3141	9939	3490	88 0
15	9954	2356	9946	2748	9938	3141	9931	3533	9923	3926	45
30	9943	2617	9933	3053	9924	3490	9914	3926	9905	4362	30
45	5.9931	0.2879	6.9919	0.3358	7.9908	0.3838	8.9896	0.4318	9.9885	0.4798	15
3 0	9918	3140	9904	3664	9890	4187	9877	4710	9863	5234	87 0
15	9904	3402	9887	3968	9871	4535	9855	5102	9839	5669	45
30	9888	3663	9869	4273	9851	4884	9832	5494	9813	6105	30
45	9872	3924	9850	4578	9829	5232	9807	5886	9786	6540	15
4 0	9854	4185	9829	4883	9805	5581	9781	6278	9756	6976	86 0
15	9835	4447	9808	5188	9780	5929	9753	6670	9725	7411	45
30	9815	4708	9784	5492	9753	6277	9723	7061	9692	7846	30
45	9794	4968	9760	5797	9725	6625	9691	7453	9657	8281	15
5 0	9772	5229	9734	6101	9696	6972	9658	7844	9619	8716	85 0
15	5.9748	0.5490	6.9706	0.6405	7.9664	0.7320	8.9622	0.8235	9.9580	0.9150	45
30	9724	5751	9678	6709	9632	7668	9586	8626	9540	9585	30
45	9698	6011	9648	7013	9597	8015	9547	9017	9497	1.0019	15
6 0	9671	6272	9617	7317	9562	8362	9507	9408	9452	0453	84 0
15	9643	6532	9584	7621	9525	8709	9465	9798	9406	0887	45
30	9614	6792	9550	7924	9486	9056	9421	1.0188	9357	1320	30
45	9584	7052	9515	8228	9445	9403	9376	0578	9307	1754	15
7 0	9553	7312	9478	8531	9404	9750	9329	0968	9255	2187	83 0
15	9520	7572	9440	8834	9360	1.0096	9280	1358	9200	2620	45
30	9487	7832	9401	9137	9316	0442	9230	1747	9144	3053	30
45	5.9452	0.8091	6.9361	0.9440	7.9269	1.0788	8.9178	1.2137	9.9087	1.3485	15
8 0	9416	8350	9319	9742	9221	1134	9124	2526	9027	3917	82 0
15	9379	8610	9276	1.0044	9172	1479	9069	2914	8965	4349	45
30	9341	8869	9231	0347	9121	1825	9011	3303	8902	4781	30
45	9302	9127	9185	0649	9069	2170	8953	3691	8836	5212	15
9 0	9261	9386	9138	0950	9015	2515	8892	4079	8769	5643	81 0
15	9220	9645	9090	1252	8960	2859	8830	4467	8700	6074	45
30	9177	9903	9040	1553	8903	3204	8766	4854	8629	6505	30
45	9133	1.0161	8989	1854	8844	3548	8700	5241	8556	6935	15
10 0	9088	0419	8937	2155	8785	3892	8633	5628	8481	7365	80 0
15	5.9042	1.0677	6.8883	1.2456	7.8723	1.4235	8.8564	1.6015	9.8404	1.7794	45
30	8995	0934	8728	2756	8660	4579	8493	6401	8325	8224	30
45	8947	1191	8772	3057	8596	4922	8421	6787	8245	8652	15
11 0	8898	1449	8714	3357	8530	5265	8346	7173	8163	9081	79 0
15	8847	1705	8655	3656	8463	5607	8271	7558	8079	9509	45
30	8795	1962	8595	3956	8394	5949	8193	7943	7992	9937	30
45	8743	2219	8533	4255	8324	6291	8114	8328	7905	2.0364	15
12 0	8689	2475	8470	4554	8252	6633	8033	8712	7815	0791	78 0
15	8634	2731	8406	4852	8178	6974	7951	9096	7723	1218	45
30	8578	2986	8341	5151	8104	7315	7867	9480	7630	1644	30
45	5.8521	1.3242	6.8274	1.5449	7.8027	1.7656	8.7781	1.9863	9.7534	2.2070	15
13 0	8462	3497	8206	5747	7950	7996	7693	2.0246	7437	2495	77 0
15	8403	3752	8137	6044	7870	8336	7604	0628	7338	2920	45
30	8342	4007	8066	6341	7790	8676	7513	1010	7237	3345	30
45	8281	4261	7994	6638	7707	9015	7421	1392	7134	3769	15
14 0	8218	4515	7921	6935	7624	9354	7327	1773	7030	4192	76 0
15	8154	4769	7846	7231	7538	9692	7231	2154	6923	4615	45
30	8089	5023	7770	7527	7452	2.0030	7133	2534	6815	5038	30
45	8023	5276	7693	7822	7364	0368	7034	2914	6705	5460	15
15 0	7956	5529	7615	8117	7274	0706	6933	3294	6593	5882	75 0
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 6.		Dist. 7.		Dist. 8.		Dist. 9.		Dist. 10.		Course.

TABLE 2.—*Traverse*—Continued.

Course.	Dist. 1.		Dist. 2.		Dist. 3.		Dist. 4.		Dist. 5.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
° ′											° ′
15 15	0.9648	0.2630	1.9296	0.5261	2.8944	0.7891	3.8591	1.0521	4.8239	1.3152	74 45
30	9636	2672	9273	5345	8909	8017	8545	0690	8182	3362	30
45	9625	2714	9249	5429	8874	8143	8498	0858	8123	3572	15
16 0	9613	2756	9225	5513	8838	8269	8450	1025	8063	3782	74 0
15	9600	2798	9201	5597	8801	8395	8402	1193	8002	3991	45
30	9588	2840	9176	5680	8765	8520	8353	1361	7941	4201	30
45	9576	2882	9151	5764	8727	8646	8303	1528	7879	4410	15
17 0	9563	2924	9126	5847	8689	8771	8252	1695	7815	4619	73 0
15	9550	2965	9100	5931	8651	8896	8201	1862	7751	4827	45
30	9537	3007	9074	6014	8612	9021	8149	2028	7686	5035	30
45	0.9524	0.3049	1.9048	0.6097	2.8572	0.9146	3.8096	1.2195	4.7620	1.5243	15
18 0	9511	3090	9021	6180	8532	9271	8042	2361	7553	5451	72 0
15	9497	3132	8994	6263	8491	9395	7988	2527	7485	5658	45
30	9483	3173	8966	6346	8450	9519	7933	2692	7416	5865	30
45	9469	3214	8939	6429	8408	9643	7877	2858	7347	6072	15
19 0	9455	3256	8910	6511	8366	9767	7821	3023	7276	6278	71 0
15	9441	3297	8882	6594	8323	9891	7764	3188	7204	6485	45
30	9426	3338	8853	6676	8279	1.0014	7706	3352	7132	6690	30
45	9412	3379	8824	6758	8235	0138	7647	3517	7059	6896	15
20 0	9397	3420	8794	6840	8191	0261	7588	3681	6985	7101	70 0
15	0.9382	0.3461	1.8764	0.6922	2.8146	1.0384	3.7528	1.3845	4.6910	1.7306	45
30	9367	3502	8733	7004	8100	0506	7467	4008	6834	7510	30
45	9351	3543	8703	7086	8054	0629	7405	4172	6757	7715	15
21 0	9336	3584	8672	7167	8007	0751	7343	4335	6679	7918	69 0
15	9320	3624	8640	7249	7960	0873	7280	4498	6600	8122	45
30	9304	3665	8608	7330	7913	0995	7217	4660	6521	8325	30
45	9288	3706	8576	7411	7864	1117	7152	4822	6440	8528	15
22 0	9272	3746	8544	7492	7816	1238	7087	4984	6359	8730	68 0
15	9255	3786	8511	7573	7766	1359	7022	5146	6277	8932	45
30	9239	3827	8478	7654	7716	1481	6955	5307	6194	9134	30
45	0.9222	0.3867	1.8444	0.7734	2.7666	1.1601	3.6888	1.5468	4.6110	1.9336	15
23 0	9205	3907	8410	7815	7615	1722	6820	5629	6025	9537	67 0
15	9188	3947	8376	7895	7564	1842	6752	5790	5940	9737	45
30	9171	3987	8341	7975	7512	1962	6682	5950	5853	9937	30
45	9153	4027	8306	8055	7459	2082	6612	6110	5766	2.0137	15
24 0	9135	4067	8271	8135	7406	2202	6542	6269	5677	0337	66 0
15	9118	4107	8235	8214	7353	2322	6470	6429	5588	0536	45
30	9100	4147	8199	8294	7299	2441	6398	6588	5498	0735	30
45	9081	4187	8163	8373	7214	2560	6326	6746	5407	0933	15
25 0	9063	4226	8126	8452	7189	2679	6252	6905	5315	1131	65 0
15	0.9045	0.4266	1.8089	0.8531	2.7034	1.2797	3.6178	1.7063	4.5223	2.1328	45
30	9026	4305	8052	8610	7078	2915	6103	7220	5129	1526	30
45	9007	4344	8014	8689	7021	3033	6028	7378	5035	1722	15
26 0	8988	4384	7976	8767	6964	3151	5952	7535	4940	1919	64 0
15	8969	4423	7937	8846	6906	3269	5875	7692	4844	2114	45
30	8949	4462	7899	8924	6848	3386	5797	7848	4747	2310	30
45	8930	4501	7860	9002	6789	3503	5719	8004	4649	2505	15
27 0	8910	4540	7820	9080	6730	3620	5640	8160	4550	2700	63 0
15	8890	4579	7780	9157	6671	3736	5561	8315	4451	2894	45
30	8870	4617	7740	9235	6610	3852	5480	8470	4351	3087	30
45	0.8850	0.4656	1.7700	0.9312	2.6550	1.3968	3.5400	1.8625	4.4249	2.3281	15
28 0	8829	4695	7659	9389	6488	4084	5318	8779	4147	3474	62 0
15	8809	4733	7618	9466	6427	4200	5236	8933	4045	3666	45
30	8788	4772	7576	9543	6365	4315	5153	9086	3941	3858	30
45	8767	4810	7535	9620	6302	4430	5069	9240	3836	4049	15
29 0	8746	4848	7492	9696	6239	4544	4985	9392	3731	4240	61 0
15	8725	4886	7450	9772	6175	4659	4900	9545	3625	4431	45
30	8704	4924	7407	9848	6111	4773	4814	9697	3518	4621	30
45	8682	4962	7364	9924	6046	4886	4728	9849	3410	4811	15
30 0	8660	5000	7321	1.0000	5981	5000	4641	2.0000	3301	5000	60 0
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Course.
	Dist. 1.		Dist. 2.		Dist. 3.		Dist. 4.		Dist. 5.		

TABLE 2.—*Traverse*—Continued.

Course.	Dist. 6.		Dist. 7.		Dist. 8.		Dist. 9.		Dist. 10.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
° ′											° ′
15 15	5.7887	1.5782	6.7535	1.8412	7.7183	2.1042	8.6831	2.3673	9.6479	2.6303	74 45
30	7818	6034	7454	8707	7090	1379	6727	4051	6363	6724	30
45	7747	6286	7372	9001	6996	1715	6621	4130	6246	7144	15
16 0	7676	6538	7288	9295	6901	2051	6514	4807	6126	7564	74 0
15	7603	6790	7203	9588	6804	2386	6404	5185	6005	7983	45
30	7529	7041	7117	9881	6706	2721	6294	5561	5882	8402	30
45	7454	7292	7030	2.0174	6606	3056	6181	5938	5757	8820	15
17 0	7378	7542	6941	0466	6504	3390	6067	6313	5630	9237	73 0
15	7301	7792	6851	0758	6402	3723	5952	6689	5502	9654	45
30	7223	8042	6760	1049	6297	4056	5835	7064	5372	3.0071	30
45	5.7144	1.8292	6.6668	2.1341	7.6192	2.4389	8.5716	2.7438	9.5240	3.0486	15
18 0	7063	8541	6574	1631	6085	4721	5595	7812	5106	0902	72 0
15	6982	8790	6479	1921	5976	5053	5473	8185	4970	1316	45
30	6899	9038	6383	2211	5866	5384	5349	8557	4832	1730	30
45	6816	9286	6285	2501	5754	5715	5224	8930	4693	2144	15
19 0	6731	9534	6186	2790	5641	6045	5097	9301	4552	2557	71 0
15	6645	9781	6086	3078	5527	6375	4968	9672	4409	2969	45
30	6558	2.0028	5985	3366	5411	6705	4838	3.0043	4264	3381	30
45	6471	0275	5882	3654	5294	7033	4706	0413	4118	3792	15
20 0	6382	0521	5778	3941	5175	7362	4572	0782	3969	4202	70 0
15	5.6291	2.0767	6.5673	2.4228	7.5055	2.7689	8.4437	3.1151	9.3819	3.4612	45
30	6200	1012	5567	4515	4934	8017	4300	1519	3667	5021	30
45	6108	1257	5459	4800	4811	8343	4162	1886	3514	5429	15
21 0	6015	1502	5351	5086	4686	8669	4022	2253	3358	5837	69 0
15	5920	1746	5241	5371	4561	8995	3881	2619	3201	6244	45
30	5825	1990	5129	5655	4433	9320	3738	2985	3042	6650	30
45	5729	2233	5017	5939	4305	9645	3593	3350	2881	7056	15
22 0	5631	2476	4903	6222	4175	9969	3447	3715	2718	7461	68 0
15	5532	2719	4788	6505	4043	3.0292	3299	4078	2554	7865	45
30	5433	2961	4672	6788	3910	0615	3149	4442	2388	8268	30
45	5.5332	2.3203	6.4554	2.7070	7.3776	3.0937	8.2998	3.4804	9.2220	3.8671	15
23 0	5230	3414	4435	7351	3640	1258	2845	5166	2050	9073	67 0
15	5127	3685	4315	7632	3503	1580	2691	5527	1879	9474	45
30	5024	3925	4194	7912	3365	1900	2535	5887	1706	9875	30
45	4919	4165	4072	8192	3225	2220	2378	6247	1531	4.0275	15
24 0	4813	4404	3948	8472	3084	2539	2219	6606	1355	0674	66 0
15	4706	4643	3823	8750	2941	2858	2059	6965	1176	1072	45
30	4598	4882	3697	9029	2797	3175	1897	7322	0996	1469	30
45	4489	5120	3570	9306	2651	3493	1733	7679	0814	1866	15
25 0	4378	5357	3442	9583	2505	3809	1568	8036	0631	2262	65 0
15	5.4267	2.5594	6.3312	2.9800	7.2356	3.4125	8.1401	3.8391	9.0446	4.2657	45
30	4155	5831	3181	3.0136	2207	4441	1233	8746	0259	3051	30
45	4042	6067	3049	0411	2056	4756	1063	9100	0070	3445	15
26 0	3928	6302	2916	0686	1904	5070	0891	9453	8.9879	3837	64 0
15	3812	6537	2781	0960	1750	5383	0719	9806	9687	4229	45
30	3696	6772	2645	1234	1595	5696	0644	4.0158	9493	4620	30
45	3579	7006	2509	1507	1438	6008	0368	0509	9298	5010	15
27 0	3460	7239	2370	1779	1281	6319	0191	0859	9101	5399	63 0
15	3341	7472	2231	2051	1121	6630	0012	1209	8902	5787	45
30	3221	7705	2091	2322	0961	6940	7.9831	1557	8701	6175	30
45	5.3099	2.7937	6.1949	3.2593	7.0799	3.7249	7.9649	4.1905	8.8499	4.6561	15
28 0	2977	8168	1806	2863	0636	7558	9465	2252	8295	6947	62 0
15	2853	8399	1662	3132	0471	7866	9280	2599	8089	7332	45
30	2729	8630	1517	3401	0305	8173	9094	2944	7882	7716	30
45	2604	8859	1371	3669	0138	8479	8905	3289	7673	8099	15
29 0	2477	9089	1223	3937	6.9970	8785	8716	3633	7462	8481	61 0
15	2350	9317	1075	4203	9800	9090	8525	3976	7250	8862	45
30	2221	9545	0925	4470	9628	9394	8332	4318	7036	9242	30
45	2092	9773	0774	4735	9456	9697	8138	4659	6820	9622	15
30 0	1962	3.0000	0622	5000	9282	4.0000	7942	5000	6603	5.0000	60 0
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Course.
	Dist. 6.		Dist. 7.		Dist. 8.		Dist. 9.		Dist. 10.		

TABLE 2.—*Traverse*—Continued.

Course.	Dist. 1.		Dist. 2.		Dist. 3.		Dist. 4.		Dist. 5.		Course.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
° ′											° ′
30 15	0.8638	0.5038	1.7277	1.0075	2.5915	1.5113	3.4553	2.0151	4.3192	2.5189	59 45
30	8616	5075	7233	0151	5849	5226	4465	0302	3081	5377	30
45	8594	5113	7188	0226	5782	5339	4376	0452	2970	5565	15
31 0	8572	5150	7142	0301	5715	5451	4287	0602	2858	5752	59 0
15	8549	5188	7098	0375	5647	5563	4196	0751	2746	5939	45
30	8526	5225	7053	0450	5579	5675	4106	0900	2632	6125	30
45	8504	5262	7007	0524	5511	5786	4014	1049	2518	6311	15
32 0	8480	5299	6961	0598	5441	5898	3922	1197	2402	6496	58 0
15	8457	5336	6915	0672	5372	6008	3829	1345	2286	6681	45
30	8434	5373	6868	0746	5302	6119	3736	1492	2170	6865	30
45	0.8410	0.5410	1.6821	1.0819	2.5231	1.6229	3.3642	2.1639	4.2052	2.7049	15
33 0	8387	5446	6773	0893	5160	6339	3547	1786	1934	7232	57 0
15	8363	5483	6726	0966	5089	6449	3451	1932	1814	7415	45
30	8339	5519	6678	1039	5017	6558	3355	2077	1694	7597	30
45	8315	5556	6629	1111	4944	6667	3259	2223	1573	7779	15
34 0	8290	5592	6581	1184	4871	6776	3162	2368	1452	7960	56 0
15	8266	5628	6532	1256	4798	6884	3064	2512	1329	8140	45
30	8241	5664	6483	1328	4724	6992	2965	2656	1206	8320	30
45	8216	5700	6433	1400	4649	7100	2866	2800	1082	8500	15
35 0	8192	5736	6383	1472	4575	7207	2766	2943	0958	8679	55 0
15	0.8166	0.5771	1.6333	1.1543	2.4499	1.7314	3.2666	2.3086	4.0832	2.8857	45
30	8141	5807	6282	1614	4423	7421	2565	3228	0706	9035	30
45	8116	5842	6231	1685	4347	7527	2463	3370	0579	9212	15
36 0	8090	5878	6180	1756	4271	7634	2361	3511	0451	9389	54 0
15	8064	5913	6129	1826	4193	7739	2258	3652	0322	9565	45
30	8039	5948	6077	1896	4116	7845	2154	3793	0193	9741	30
45	8013	5983	6025	1966	4038	7950	2050	3933	0063	9916	15
37 0	7986	6018	5973	2036	3959	8054	1945	4073	3.9932	3.0091	53 0
15	7960	6053	5920	2106	3880	8159	1840	4212	9800	0365	45
30	7934	6088	5867	2175	3801	8263	1734	4350	9668	0438	30
45	0.7907	0.6122	1.5814	1.2244	2.3721	1.8367	3.1628	2.4489	3.9534	3.0611	15
38 0	7880	6157	5760	2313	3640	8470	1520	4626	9400	0783	52 0
15	7853	6191	5706	2382	3560	8573	1413	4764	9266	0955	45
30	7826	6225	5652	2450	3478	8675	1304	4901	9130	1126	30
45	7799	6259	5598	2518	3397	8778	1195	5037	8994	1296	15
39 0	7771	6293	5543	2586	3314	8880	1086	5173	8857	1466	51 0
15	7744	6327	5488	2654	3232	8981	0976	5308	8720	1635	45
30	7716	6361	5432	2722	3149	9082	0865	5443	8581	1804	30
45	7688	6394	5377	2789	3065	9183	0754	5578	8442	1972	15
40 0	7660	6428	5321	2856	2981	9284	0642	5712	8302	2139	50 0
15	0.7632	0.6461	1.5265	1.2922	2.2897	1.9384	3.0529	2.5845	3.8162	3.2306	45
30	7604	6494	5208	2989	2812	9483	0416	5978	8020	2472	30
45	7576	6528	5151	3055	2727	9583	0303	6110	7878	2638	15
41 0	7547	6561	5094	3121	2641	9682	0188	6242	7735	2803	49 0
15	7518	6593	5037	3187	2555	9780	0074	6374	7592	2967	45
30	7490	6626	4979	3252	2469	9879	2.9958	6505	7448	3131	30
45	7461	6659	4921	3318	2382	9976	9842	6635	7303	3294	15
42 0	7431	6691	4863	3383	2294	2.0074	9726	6765	7157	3457	48 0
15	7402	6724	4804	3447	2207	0171	9609	6895	7011	3618	45
30	7373	6756	4746	3512	2118	0268	9491	7024	6864	3780	30
45	0.7343	0.6788	1.4686	1.3576	2.2030	2.0364	2.9373	2.7152	3.6716	3.3940	15
43 0	7314	6820	4627	3640	1941	0460	9254	7280	6568	4100	47 0
15	7284	6852	4567	3704	1851	0555	9135	7407	6419	4259	45
30	7254	6884	4507	3767	1761	0651	9015	7534	6269	4418	30
45	7224	6915	4447	3830	1671	0745	8895	7661	6118	4576	15
44 0	7193	6947	4387	3893	1580	0840	8774	7786	5967	4733	46 0
15	7163	6978	4326	3956	1489	0934	8652	7912	5815	4890	45
30	7133	7009	4265	4018	1398	1027	8530	8036	5663	5045	30
45	7102	7040	4204	4080	1306	1120	8407	8161	5509	5201	15
45 0	7071	7071	4142	4142	1213	1213	8284	8284	5355	5355	45 0
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 1.		Dist. 2.		Dist. 3.		Dist. 4.		Dist. 5.		Course.

TABLE 2.—*Traverse*—Continued.

Course.	Dist. 6.		Dist. 7.		Dist. 8.		Dist. 9.		Dist. 10.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
° ′											° ′
30 15	5. 1830	3. 0226	6. 0468	3. 5264	6. 9107	4. 0302	7. 7745	4. 5340	8. 6384	5. 0377	59 45
30	1698	0452	0314	5528	8930	0603	7547	5678	6163	0754	30
45	1564	0678	0158	5791	8753	0903	7347	6016	5941	1129	15
31 0	1430	0902	0002	6053	8573	1203	7145	6353	5717	1504	59 0
15	1295	1126	5. 9844	6314	8393	1502	6942	6690	5491	1877	45
30	1158	1350	9685	6575	8211	1800	6738	7025	5264	2250	30
45	1021	1573	9525	6835	8028	2097	6532	7359	5035	2621	15
32 0	0883	1795	9363	7094	7844	2394	6324	7693	4805	2992	58 0
15	0744	2017	9201	7353	7658	2689	6116	8025	4573	3361	45
30	0603	2238	9037	7611	7471	2984	5905	8357	4339	3730	30
45	5. 0462	3. 2458	5. 8873	3. 7868	6. 7283	4. 3278	7. 5694	4. 8688	8. 4104	5. 4097	15
33 0	0320	2678	8707	8125	7094	3571	5480	9018	3867	4464	57 0
15	0177	2898	8540	8381	6903	3863	5266	9346	3629	4829	45
30	0033	3116	8372	8636	6711	4155	5050	9674	3389	5194	30
45	4. 9888	3334	8203	8890	6518	4446	4832	5. 0001	3147	5557	15
34 0	9742	3552	8033	9144	6323	4735	4613	0327	2904	5919	56 0
15	9595	3768	7861	9396	6127	5024	4393	0652	2659	6280	45
30	9448	3984	7689	9648	5930	5312	4171	0977	2413	6641	30
45	9299	4200	7515	9900	5732	5600	3948	1300	2165	7000	15
35 0	9149	4415	7341	4. 0150	5532	5886	3724	1622	1915	7358	55 0
15	4. 8998	3. 4629	5. 7165	4. 0400	6. 5331	4. 6172	7. 3498	5. 1943	8. 1664	5. 7715	45
30	8847	4842	6988	0649	5129	6456	3370	2263	1412	8070	30
45	8694	5055	6810	0897	4926	6740	3042	2582	1157	8425	15
36 0	8541	5267	6631	1145	4721	7023	2812	2901	0902	8779	54 0
15	8387	5479	6451	1392	4516	7305	2580	3218	0644	9131	45
30	8231	5689	6270	1638	4309	7586	2347	3534	0386	9482	30
45	8075	5899	6088	1883	4100	7866	2113	3849	0125	9832	15
37 0	7918	6109	5904	2127	3891	8145	1877	4163	7. 9864	6. 0182	53 0
15	7760	6318	5720	2371	3680	8424	1640	4476	9600	0529	45
30	7601	6526	5535	2613	3468	8701	1402	4789	9335	0876	30
45	4. 7441	3. 6733	5. 5348	4. 2855	6. 3255	4. 8977	7. 1162	5. 5100	7. 9069	6. 1222	15
38 0	7281	6940	5161	3096	3041	9253	0921	5410	8801	1566	52 0
15	7119	7146	4972	3337	2825	9528	0679	5718	8532	1909	45
30	6956	7351	4783	3576	2609	9801	0435	6026	8261	2251	30
45	6793	7555	4592	3815	2391	5. 0074	0190	6333	7988	2592	15
39 0	6629	7759	4400	4052	2172	0346	6. 9943	6639	7715	2932	51 0
15	6464	7962	4207	4289	1951	0616	9695	6943	7439	3271	45
30	6297	8165	4014	4525	1730	0886	9446	7247	7162	3608	30
45	6131	8366	3819	4761	1507	1155	9196	7550	6884	3944	15
40 0	5963	8567	3623	4995	1284	1423	8944	7851	6604	4279	50 0
15	4. 5794	3. 8767	5. 3426	4. 5229	6. 1059	5. 1690	6. 8691	5. 8151	7. 6323	6. 4612	45
30	5624	8967	3228	5461	0832	1956	8437	8450	6041	4945	30
45	5454	9166	3030	5693	0605	2221	8181	8748	5756	5276	15
41 0	5283	9364	2830	5924	0377	2485	7924	9045	5471	5606	49 0
15	5110	9561	2629	6154	0147	2748	7666	9341	5184	5935	45
30	4937	9757	2427	6383	5. 9916	3010	7406	9636	4896	6262	30
45	4763	9953	2224	6612	9685	3271	7145	9929	4606	6588	15
42 0	4589	4. 0148	2020	6839	9452	3530	6883	6. 0222	4314	6913	48 0
15	4413	0342	1815	7066	9217	3789	6620	0513	4022	7237	45
30	4237	0535	1609	7291	8982	4047	6355	0803	3728	7559	30
45	4. 4059	4. 0728	5. 1403	4. 7516	5. 8746	5. 4304	6. 6089	6. 1092	7. 3432	6. 7880	15
43 0	3881	0920	1195	7740	8508	4560	5822	1380	3135	8200	47 0
15	3702	1111	0986	7963	8270	4815	5553	1666	2837	8518	45
30	3522	1301	0776	8185	8030	5068	5284	1952	2537	8835	30
45	3342	1491	0565	8406	7789	5321	5013	2236	2236	9151	15
44 0	3160	1680	0354	8626	7547	5573	4741	2519	1934	9466	46 0
15	2978	1867	0141	8845	7304	5823	4467	2801	1630	9779	45
30	2795	2055	4. 9928	9064	7060	6073	4193	3082	1325	7. 0091	30
45	2611	2241	9713	9281	6815	6321	3917	3361	1019	0401	15
45 0	2426	2426	9497	9497	6569	6569	3640	3640	0711	0711	45 0
	Dep.	Lat.	Dep.	at.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Course.
	Dist. 6.		Dist. 7.		Dist. 8.		Dist. 9.		Dist. 10.		

ANEROID ELEVATIONS.

The pocket aneroid barometer is not a very accurate instrument, but satisfactory results may generally be obtained by using the following method: Two aneroids are necessary. Both should be compared and set at some established elevation, such as a bench mark of the Geological Survey or at a railway station. Any necessary correction may be made by sliding the rim or by means of the small screw on the back of the barometer, which will move the hand to the proper reading. After arriving at the camp from which the survey is to be made both aneroids should be read and the readings entered in the notes. One aneroid should be kept in camp while the other is used in the field, and they should be compared twice a day, say at 7 a. m. and 7 p. m. The camp barometer will then show the change in atmospheric pressure from time to time during the survey, and the difference between the two, when the field barometer is being used at a distance, will give the difference in elevation between the camp and the point where the field barometer was read. If the two barometers agree in the morning and do not agree at evening the difference, if material, may be proportioned during the day's notes, assuming the camp barometer to be correct. The scale of "mercury inches," generally graduated on aneroids, is not to be used.

ELEVATIONS FROM VERTICAL ANGLES.

When the distance to a mountain or other object is known its elevation above the surveyor may be determined. A vertical angle is measured with a clinometer

or clinometer-compass, and the difference in elevation can be determined from the table. Information of this character assists greatly in the preparation of a map, and this method should be used when a peak is inaccessible or not likely to be occupied during the present survey. If both the distance and elevation of a peak are known, and the surveyor desires the elevation of the station which he is then occupying, this process is easily reversed. The table is prepared to miles of distance, and if intermediate fractional miles are needed the ratio may be interpolated.

The method of determining the distance of a peak or other salient topographic point is illustrated in the various plane-table methods. If compass sights are taken from two or more known points the intersections may be platted with a protractor or computed.[a]

Then:

$$\frac{\text{Distance } AB \times \text{sine of angle } B}{\text{Sine of angle } C} = \text{distance } AC$$

Or:

$$\frac{\text{Distance } AB \times \text{sine of angle } A}{\text{Sine of angle } C} = \text{distance } BC$$

[a] The following is the method of computing the sides of a triangle when two angles and one side are known: The angle opposite the known side is equal to 180° minus the sum of the two known angles. The sine of an angle is the same as its departure (in the traverse table) for distance 1. A and B represent the two known angles and their distance apart; C is the opposite angle.

TABLE 3.—*Difference of altitude between the "station" occupied by the surveyor, of which the altitude is known, and a higher distant object whose altitude is desired.*

[Difference of altitude in feet—add to station altitude.]

Vertical angle above a level line.	Distance to object, in miles.									
	1	2	3	4	5	6	7	8	9	10
0°00′	5	7	10	14	19	25	33	41	51	62
15	28	53	79	106	134	163	194	225	258	292
30	51	99	148	198	249	301	356	410	466	523
45	74	145	217	290	365	440	517	594	673	753
1°00′	97	191	286	383	480	578	678	778	880	984
15	120	237	356	475	595	716	839	963	1,088	1,214
30	143	283	425	567	710	855	1,001	1,147	1,295	1,445
45	166	330	494	659	826	993	1,162	1,332	1,503	1,675
2°00′	189	376	563	752	941	1,131	1,324	1,516	1,710	1,906
15	212	422	632	844	1,056	1,270	1,485	1,701	1,918	2,137
30	235	468	702	936	1,172	1,408	1,647	1,885	2,126	2,367
45	259	514	771	1,028	1,287	1,547	1,808	2,070	2,334	2,598
3°00′	282	560	840	1,121	1,403	1,685	1,970	2,255	2,541	2,829
15	305	607	909	1,213	1,518	1,824	2,132	2,440	2,749	3,060
30	328	653	979	1,306	1,634	1,963	2,294	2,625	2,957	3,291
45	351	699	1,048	1,398	1,749	2,101	2,455	2,810	3,166	3,523
4°00′	374	745	1,118	1,491	1,865	2,240	2,617	2,995	3,374	3,754
15	397	792	1,187	1,583	1,981	2,379	2,780	3,180	3,582	3,986
30	420	838	1,257	1,676	2,097	2,518	2,942	3,365	3,791	4,217
45	444	884	1,326	1,769	2,213	2,657	3,104	3,551	4,000	4,449
5°00′	467	931	1,396	1,862	2,329	2,797	3,267	3,737	4,208	4,681
15	490	977	1,466	1,955	2,445	2,936	3,429	3,922	4,418	4,914
30	513	1,024	1,535	2,048	2,561	3,075	3,592	4,108	4,627	5,146
45	537	1,070	1,605	2,141	2,677	3,215	3,755	4,294	4,836	5,379
6°00′	560	1,117	1,675	2,234	2,794	3,355	3,918	4,481	5,046	5,612
15	583	1,164	1,745	2,327	2,910	3,495	4,081	4,667	5,255	5,845
30	607	1,210	1,815	2,420	3,027	3,634	4,244	4,854	5,465	6,078
45	630	1,257	1,885	2,514	3,144	3,775	4,407	5,040	5,675	6,311
7°00′	653	1,304	1,955	2,607	3,261	3,915	4,571	5,227	5,886	6,545
15	677	1,350	2,025	2,701	3,378	4,055	4,735	5,415	6,096	6,779
30	700	1,397	2,095	2,795	3,595	4,196	4,899	5,602	6,307	7,013
45	724	1,444	2,166	2,888	3,612	4,337	5,063	5,790	6,518	7,248
8°00′	747	1,491	2,236	2,982	3,729	4,477	5,227	5,977	6,729	7,483
15	771	1,538	2,307	3,076	3,847	4,618	5,392	6,166	6,941	7,718
30	794	1,585	2,377	3,170	3,964	4,760	5,557	6,354	7,153	7,953
45	818	1,632	2,448	3,265	4,082	4,901	5,722	6,542	7,365	8,189
9°00′	841	1,680	2,519	3,359	4,200	5,043	5,887	6,731	7,577	8,425
15	865	1,727	2,590	3,454	4,319	5,185	6,053	6,920	7,790	8,661
30	889	1,774	2,661	3,548	4,437	5,327	6,218	7,109	8,003	8,898
45	912	1,821	2,732	3,643	4,556	5,469	6,384	7,299	8,217	9,135

TABLE 3.—*Difference of altitude between the "station" occupied by the surveyor, of which the altitude is known, and a higher distant object whose altitude is desired*—Continued.

[Difference of altitude in feet—add to station altitude.]

Vertical angle above a level line.	Distance to object, in miles.									
	1	2	3	4	5	6	7	8	9	10
10°00′	936	1,869	2,803	3,738	4,674	5,611	6,550	7,489	8,430	9,372
15	960	1,917	2,874	3,833	4,793	5,754	6,717	7,679	8,644	9,610
30	984	1,964	2,946	3,928	4,912	5,897	6,883	7,870	8,858	9,848
45	1,007	2,012	3,017	4,024	5,031	6,040	7,050	8,061	9,073	10,087
11°00′	1,031	2,060	3,089	4,119	5,151	6,183	7,217	8,252	9,288	.....
15	1,055	2,108	3,161	4,215	5,270	6,327	7,385	8,443	9,504	.....
30	1,079	2,155	3,233	4,311	5,390	6,470	7,553	8,635	9,719	.....
45	1,103	2,204	3,305	4,407	5,510	6,615	7,721	8,827	9,935	.....
12°00′	1,127	2,252	3,377	4,503	5,631	6,759	7,889	9,019	.....	.....
15	1,151	2,300	3,449	4,600	5,751	6,904	8,058	9,212	.....	.....
30	1,176	2,348	3,522	4,696	5,872	7,048	8,227	9,405	.....	.....
45	1,200	2,397	3,594	4,793	5,993	7,194	8,396	9,599	.....	.....
13°00′	1,224	2,445	3,667	4,890	6,114	7,339	8,566	.....	.....	.....
15	1,248	2,494	3,740	4,987	6,235	7,485	8,736	.....	.....	.....
30	1,273	2,542	3,813	5,084	6,357	7,631	8,906	.....	.....	.....
45	1,297	2,591	3,886	5,182	6,479	7,777	9,077	.....	.....	.....
14°00′	1,321	2,640	3,959	5,280	6,601	7,924	.....	.....	.....	.....
15	1,346	2,689	4,033	5,378	6,724	8,071	.....	.....	.....	.....
30	1,371	2,738	4,107	5,476	6,847	8,218	.....	.....	.....	.....
45	1,395	2,787	4,180	5,574	6,970	8,366	.....	.....	.....	.....
15°00′	1,420	2,837	4,254	5,673	7,093	.....	.....	.....	.....	.....
15	1,444	2,886	4,327	5,771	7,216	.....	.....	.....	.....	.....
30	1,469	2,935	4,402	5,870	7,339	.....	.....	.....	.....	.....
45	1,494	2,985	4,477	5,970	7,463	.....	.....	.....	.....	.....

This table is corrected for earth curvature, refraction, and the height of the instrument used at the station (4½ feet).

MEASUREMENTS.

The most frequent source of error in pacing, chaining, or steel taping is in counting the tallies—assuming that the mechanical part of the work is well done. The memory should not be trusted. The only safe plan is to enter each tally in the field notes as soon as that tally is completed and the pins or stake have been counted

by both chainmen and before the next tally is begun. When timber is being estimated along the survey line this error is not likely to occur, as the numbers on the timber sheets are a check upon the work.

If a pair of amateur chainmen went over some open level country and reported a distance of 174.62 chains, an error, if one existed, would probably be found in the "tens" or tallies, and a resurvey would give 164.62 or 184.62 chains. The standard chain has a length of 66 feet. If any other unit of linear measure is used, it must be made clear in the notes.

FIELD NOTES.

Notes of survey should show exactly what was done in the field, including the errors of courses or measurements. In resurveying lines, it is no reflection on the survey party if it does not "check up" exactly, but it is rather expected that a trial or "random line" will not strike a corner nor the measurement prove exactly as "returned" by the original surveyor. It is important, however, to know what the error or difference is discovered to be.

When a notebook contains the field notes of only one survey, the purpose for which the survey was made should be plainly marked on the cover as well as on the first page. If it contains the notes of more than one survey, the title of a survey should be written at the top of each page, and the book should be indexed on the first page. Each book should be numbered and paged. When the notes for a survey do not follow in

regular order in a notebook be sure to refer to the page where the continuation can be found and at that point refer back by page number to the former notes.

It is a good plan to make numerous explanatory sketches on the right-hand pages of the notebooks, leaving nothing to the memory, and particularly the direction of the flow of streams should be shown by arrows. If the surveyor will always imagine that he might stop work at any moment, and someone else may be obliged to continue the survey, and will keep his notes so clearly that this would be easy, then they are apt to be a reliable record. Never erase notes—cross them out and mark them "abandoned."

Field notes should never be crowded into a notebook or be written as a continuous recital, but should be tabulated clearly that they may be readily platted by any surveyor or draftsman. A good form for keeping notes is here shown.

SPECIMEN NOTES.

_____ National Forest.

Resurvey of east boundary of Sec. 24, T. 19 N., R. 14 E.

June 16, 1907.

Weather clear.

I corrected both *aneroids* at the benchmark at . . . . which has an elevation of . . . . ft.

Made camp 5.30 p. m. Sec. 24, T. 19 N., R. 14 E.

7 p. m. Camp barometer reads 4,850′.

Field barometer reads 4,860′.

At 9 p. m. observed *Polaris* and find the variation at camp to be 19° east.

[Begin a new page.]

June 17, 1907.
Weather clear.

7 a. m. Camp barometer 4,850′.
Field barometer 4,860′.

Resurvey of east boundary of sec. 24, T. 19 N., R. 14 E., in the . . . . . National Forest. The *original survey* was made in 1872, with variation 18½° east. Allowing for the reported increase, the variation should be about 19° 05′.

		Elev.
	From the southeast corner of sec. 24	4,780′
	Ran *north*, var. 19° east.	
10.00 ch.	near 36″ yellow pine	4,720′
20.00	in thicket of firs	4,680′
24.50	creek, 4 links wide, flows S. W	4,660′
30.00	at foot of steep slope	4,740′
40.00	on steep sidehill, S. E	4,920′
40.23	to a point 15 links west of ¼ corner on east side sec. 24.	
	Original blazes are almost obliterated. Made new blazes.	
	From the ¼ corner on east side of sec. 24.	
	Ran *north*, var. 19° east.	
10.00	enter burned area	5,050′
13.60	top of hill N. E. and S. W	5,120′

From this point I take *vertical angles* on some high points in unsurveyed T. 19 N., R. 15 E., as follows:

N. 24¼ E. 3 miles, vertical angle 1½°	5,545′
N. 37¼ E. 2¼ miles, vertical angle ¼°	5,186′
N. 89° E. ? miles, vertical angle 1¾°	
S. 43½ E. 4 miles, vertical angle 1°	5,503′
S. 10° E. 3¼ miles, vertical angle ¾°	5,355′

thence continue *north*.

20.00	heavy litter	5,075′
27.30	leave burn	
30.00	in good reproduction yellow pine	4,900′

		Elev.
39.85	to a point 20 links east of NE. cor. of sec. 24. Witness trees standing, but stake almost destroyed. Set new stake with the proper marks and U.S.F.S. on SW. side	4,850′
	etc., etc.	
7 p. m.	Camp barometer, 4,870′.	
	Field barometer, 4,880′.	

ROAD, STREAM, OR SUMMIT MEANDERS.

The method of keeping meander notes differs from the above. Each course begins a new tally, and any intermediate distances are entered in a third column. The second column may then be added to determine the total distance surveyed, viz:

_____ National Forest.
Meanders in unsurveyed T. 19 N., R. 15 E.

June 18, 1907.
Weather cloudy.

7 a. m.	Camp barometer, 4,880′.	
	Field barometer, 4,890′.	
	From a point 13.60 ch. north of ¼ cor. on the east side of sec. 24.	
	Ran *along summit*, var. 19° east.	
N. 24 E.	9.00 ch. at 6.00 leave burn	5,200′
N. 39½ E.	17.50 at 3.00 trail N. and S	5,125′
N. 48¼ E.	11.20 _____	5,175′
S. 86 E.	14.60 highest point on summit	5,320′
	At this point the summit divides; one branch bearing SE. and the other SW.	
	Continuing the meanders:	
	Ran *down gulch*, between the two divides.	
	Var. 19° east.	
N. 89 E.	18.00 ch. spring	5,150′

		Elev.
N. 75 E. 15.00	meadow, 2 acres	5,025′
S. 83 E. 4.00	falls, 10 feet	4,975′
N. 80 E. 22.20	at 18.00 small tributary from the south	4,900′
N. 86 E. 9.00	at 2.30 the notice of the Morning Star mining claim bears S. 1.50; at 3.40 mining cabin	4,875′
etc., etc.		

TYING IN.

It is frequently necessary to make surveys of ranger stations or for timber sales in areas which have not been previously surveyed or mapped. It is imperative that some connection should be surveyed between the nearest or most convenient established point and the initial point of the survey which is to be made. Otherwise the survey will not determine the location of the area under consideration. The nature of the country and the distance necessary to be run will suggest which of the following methods may be employed:

(1) Measure a line north, south, east, or west to intersect a Government survey line. Then tie to the nearest corner, quarter corner, meander corner, milepost, grant corner, or other point which is of official record.

(2) Or run a traverse (meander) over a road, trail, open or easy country to such points.

(3) Or if no Land Office surveys have been made nearer than, say, 5 miles, but there is a Geological Survey sheet, then tie to a bench mark, triangulation station, forks of a road, forks of a stream which has not changed its bed, or a house which is shown on the sheet. Accompany your report with a tracing or description which will show unmistakably the point used. If you

tie to a mineral monument, or to some corner of a patented mining claim, give a clear description.

(4) Or if no official surveys have been made within practicable distance, proceed as follows: Establish and witness a permanent monument, marked F.S.M This may be at the initial point of your survey. From this point run a traverse to some outlook where compass or plane-table bearings may be taken on a number of peaks or other definite landmarks which may be visible. Give their estimated distances. State approximately what unsurveyed section the land would be in, or its latitude and longitude. The map accompanying such a survey should show any divide, stream, or trail in the immediate vicinity, and particularly the name of the watershed. Detailed instructions on this subject are given in National Forest Order 23, Part 4, dated April 23, 1907.

PLANE TABLE.

For making any map the plane table is the best instrument in use. Instead of taking notes, as in running compass lines, the surveyor plats his work in the field and can thus always see the progress made. Errors and omissions are discovered quickly and rectified.

The paper upon which the map is to be made is fastened to the plane-table board by thumb tacks, and upon it rests the alidade, a straightedge or ruler with folding sights like a compass. From a point on the paper which represents the starting point on the ground over which the table is standing the surveyor draws lines on the paper with the alidade to the various topographic

features which are to be mapped. From start to finish of the survey it must at all stations retain the same orientation—that is to say, at every station where the table is set up its sides must be exactly parallel to its position at the original station.

There are several methods, all based upon the same

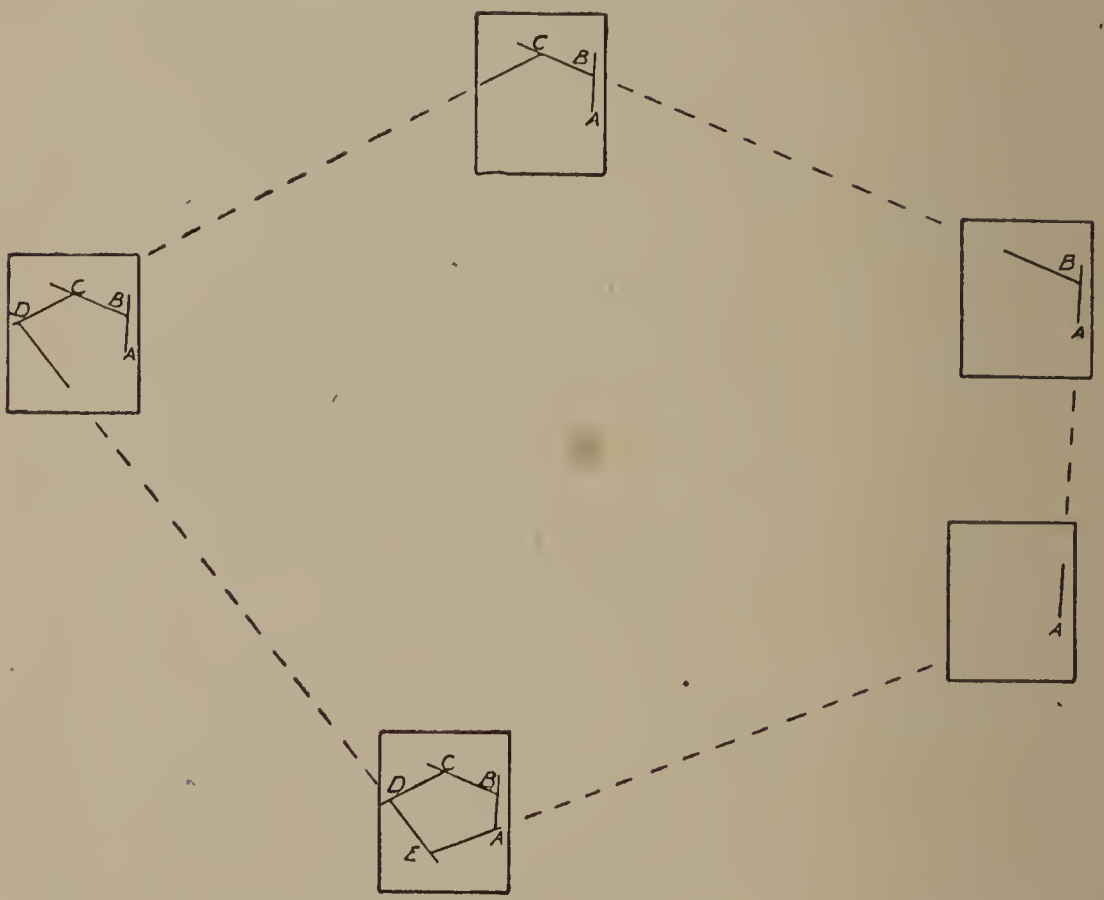


FIG. 3.—Plane-table method in which the table is set up at all the stations.

principles. If an isolated block of forest is to be bounded by a survey, the method would be:

Set up at A with one side of the table bearing approximately north and south. As A is near the southeast corner of the tract, begin to draw at the corresponding place on the paper. With the alidade draw a line from A toward B. Measure the distance AB on the

ground and scale the proportionate distance on the paper. Set the table at B. With the alidade on the drawn line take a backsight on A. The table will then be oriented or parallel to its position when at A. Draw a line on the paper from B toward C. Measure it and scale on the map. Proceed as before and the result will

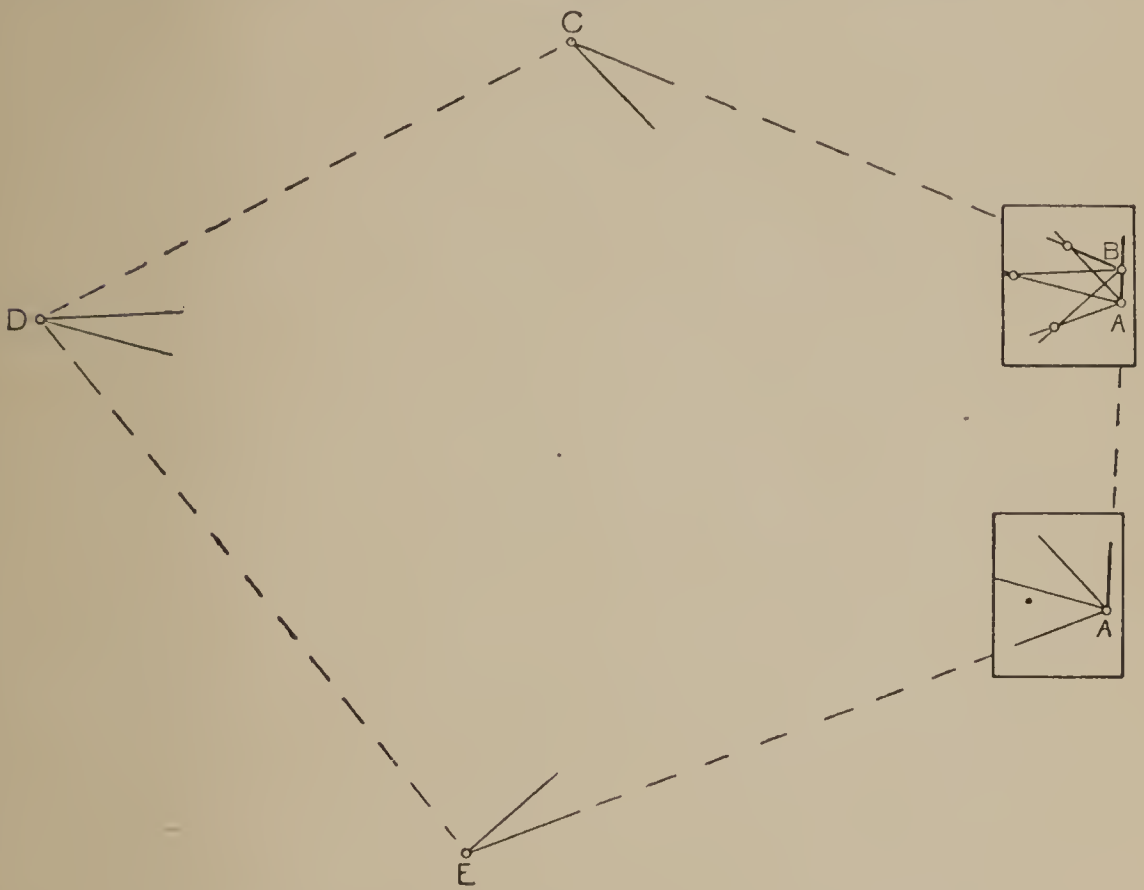


FIG. 4.—Plane-table method in which the table is set up at two stations and the remaining three are located by intersections.

be a map which will truly represent the lines on the ground. (See fig. 3.)

In this case the points C and D were not visible from A, but if, instead of being a block of forest, the area was an open meadow, then a second method would be used. Set up at A. Draw lines to B, C, D, and E. Measure AB. Set up at B. Orient on A. Draw lines to

C, D, and E. The intersections of the line will give the other three points. The line AB is a base line. (See fig. 4.)

The third method is an extension of the second and involves some near-by points which can not be located

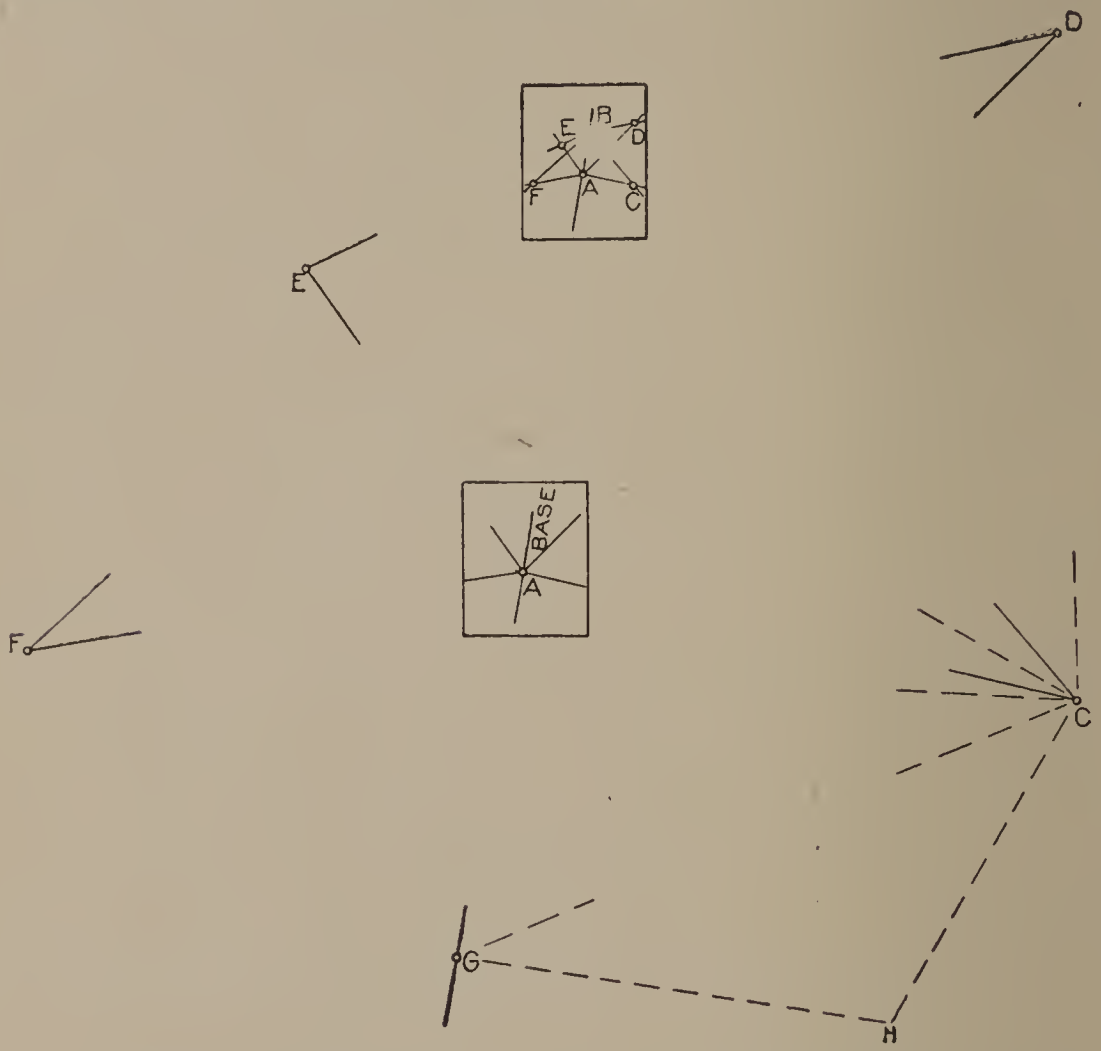


FIG. 5.—Plane-table method of locating points on both sides of a base line which are to be occupied later and the survey extended.

from the base line. From A and B the points C, D, E, and F are intersected, and one sight is taken on G, which is obviously too nearly in line with the base line to be accurately intersected. Subsequently the table is set up at C and oriented by taking sights on A, B,

D, E, and F. It is then easy to intersect G, and also get a sight on H, which was not visible before. H may be intersected from G. (See fig. 5.)

A fourth method is employed when the table must be set up at an unknown point from which three or

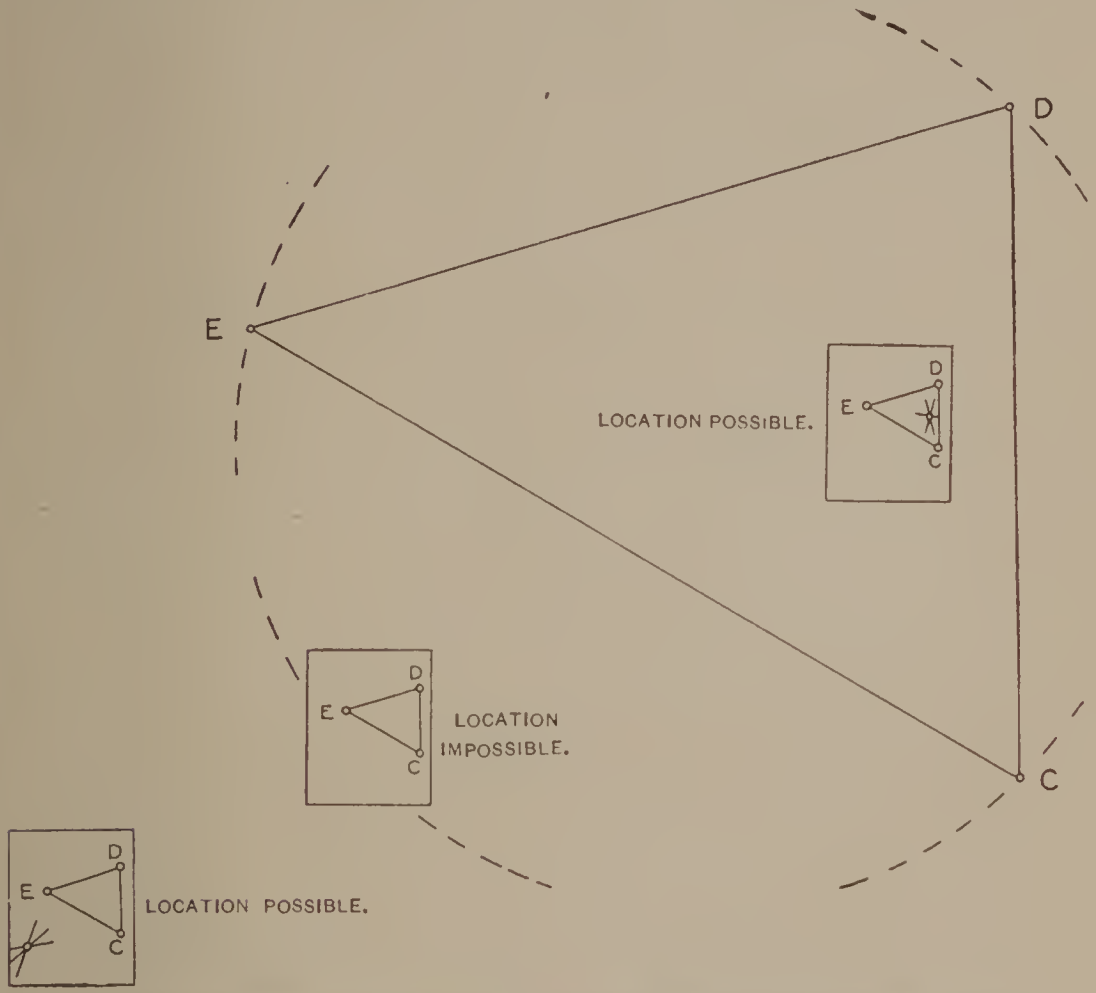


FIG. 6.—Plane-table method of finding location from three points.

more known points are visible. This is the "three-point problem," in which the surveyor "picks up" his location. Suppose that C, D, and E were located by the third method and are high and well-defined peaks. They form a triangle which can be accurately platted on the paper, and the best plan is to prick in the points with a fine needle. The surveyor will then proceed

by setting up the table at the point which is to be located and from which he can see the three peaks. Orient approximately by compass. With the alidade draw lines from each peak toward the point of set-up. If the three lines intersect the desired point is located, except as noted below. If the lines do not intersect, the orientation may be changed until they do, but an easier plan is to fasten a piece of tracing cloth on the table and assume a point from which the lines may be drawn toward the peaks. The tracing may then be shifted over the paper to find a position at which the lines will exactly cover the three needle holes on the paper. This method is reliable when the desired location is within the triangle, but it is useless when the table is set up on or near a circle which would pass through the three peaks. For this reason four or more points should be used if possible. (See fig. 6, p. 31.)

MAP MAKING IN THE FIELD.

After the salient points of the topography have been located by plane table, and the roads, streams, or summits have been traversed by compass surveys, it remains for the surveyor to sketch in the contours. Some of this may be done when the peaks are located and when the distances are chained, and the result is a skeleton map upon which it remains to fill in the balance by the eye. This is a matter of practice. It is an excellent plan to learn to read contour maps, such as are published by the Geological Survey, and the student should provide himself with a topographic sheet of some region with which he is well acquainted and learn to identify the relief with its contours. When this is mastered a good contour map will be almost as graphic as a miniature model of the country.

In sketching contours it is of great assistance to imagine the sea level raised. Thus, if the 5,000-foot contour is being sketched, we may imagine that the salt waters of the earth are raised 5,000 feet higher than they now are. It is evident that the true contour would follow the shore line which is thus imagined and that bays and harbors, islands, straits, etc., would result. It is evident that contour lines can not cross each other or themselves and that they must connect somewhere, either on the map which is being prepared or in some other region.

The contour map, when thus prepared, is only a base map for other data to be collected for the Forest Service. Some of this data may be collected as the survey proceeds, such as the classification of the land, timber, woodland, barren, etc., or the composition and stand of a forest. When the plane-table map is being made in the field the paper is necessarily covered with pencil notes and lines which give the names of points, elevations, directions, etc. There is no need to encumber this map with other figures or names which may be confusing or lead to error. A better plan is to cover the map with a piece of tracing cloth, with the dull side up, which may be thumb-tacked along one side only, that it may hang back out of the way when work is being done on the base map. On this the burns, windfalls, barren areas, or stand may be sketched either in black or with colored crayons without smearing the base map or obliterating any of its topographic data. Some salient points on the base map should be copied on the tracing cloth so that the two may be registered at any time, for the paper may shrink or the cloth may stretch.

FINAL MAPS.

These should be prepared in accordance with the plan described in the circular of April 6, 1907, "Preparation of the Forest Atlas." In this scheme every map prepared in the field covers one or more pages of the Forest Atlas, which is being compiled in the Forest Service at Washington. All field men have been supplied with legend page and sample pages from the atlas, illustrating the standards which have been adopted.

The coloring tints which are used in the classification scheme may be prepared as follows:

Forest Atlas—Color prescriptions.

	Parts.
Commercial timber:	
Less than 2,000 board feet per acre—	
Sanfords green ink	2
Pomeroys yellow ink	1
Water	3
2,000 to 5,000 board feet per acre—	
Sanfords green ink	1
Water	3
5,000 to 10,000 board feet per acre—Sanfords green ink.	
10,000 to 25,000 board feet per acre—	
Higgins brown ink	3
Sanfords green ink	3
Pomeroys yellow ink	2
25,000 to 50,000 board feet per acre—	
Higgins brown ink	4
Sanfords green ink	2
Pomeroys yellow ink	1
Water	7
Woodland, cordwood, etc.:	
Sanfords green ink	1
Pomeroys yellow ink	2
Water	8

	Parts.
Chaparral or brush:	
Higgins brown ink	1
Water	5
Sagebrush:	
Higgins brown ink	3
Pomeroys yellow ink	2
Higgins orange ink	2
Water	10
Grass land, parks, etc.:	
Pomeroys yellow ink	1
Water	1
Barren land:	
Higgins black ink	1
Water	20
Burn, forest cover established:	
Sanfords green ink	1
Pomeroys yellow ink	2
Water	8
Old cuttings:	
Higgins brick-red ink	1
Water	3
Cultivated: Higgins Indian red ink, or Higgins brick-red ink.	
Mineral lands: Higgins orange ink.	
Open for cattle and horses only:	
Higgins brick-red ink	1
Water	3
Open for sheep and goats only:	
Pomeroys yellow ink	1
Water	1
Closed for all stock: Higgins orange ink.	
Driveways for stock:	
Higgins black ink	1
Water	20

When timber or woodland has been partly burned the lining for burns may be used on top of the green. When partly cut over, or culled, the proper signs may be used in the same manner.

A map should show plainly the information it is intended to convey, and artistic flourishes, fancy type, or border designs are useless. It should show what it is, where it is, the scale, who made it, and the date. If it is from an original survey the magnetic variation should be given. On the borders of the map, if the area shown covers more than one township, the township and range numbers should be given, and also, if possible, one or more meridians and parallels. If a degree meridian does not fall in the map, then some intermediate may be given, such as 10′ or 20′. Table 4 will be found convenient.

TABLE 4.—*Lengths of degrees on meridians and parallels at different latitudes on the earth.*

At latitude—	Length of 1° on meridians.	Length of 1° on parallels.
	Miles.	*Miles.*
26°	68.84	62.21
27	68.85	61.68
28	68.86	61.12
29	68.87	60.55
30	68.88	59.96
31	68.89	59.34
32	68.90	58.72
33	68.91	58.07
34	68.92	57.41
35	68.93	56.72
36	68.95	56.03
37	68.96	55.31
38	68.97	54.58
39	68.98	53.83
40	68.99	53.06
41	69.01	52.28
42	69.02	51.48
43	69.03	50.67
44	69.04	49.84
45	69.05	49.00
46	69.07	48.14
47	69.08	47.26
48	69.09	46.37
49	69.10	45.47

The rectangular surveys of the United States Land Office control throughout the West and divide the land surfaces into squares which may be divided and sub-

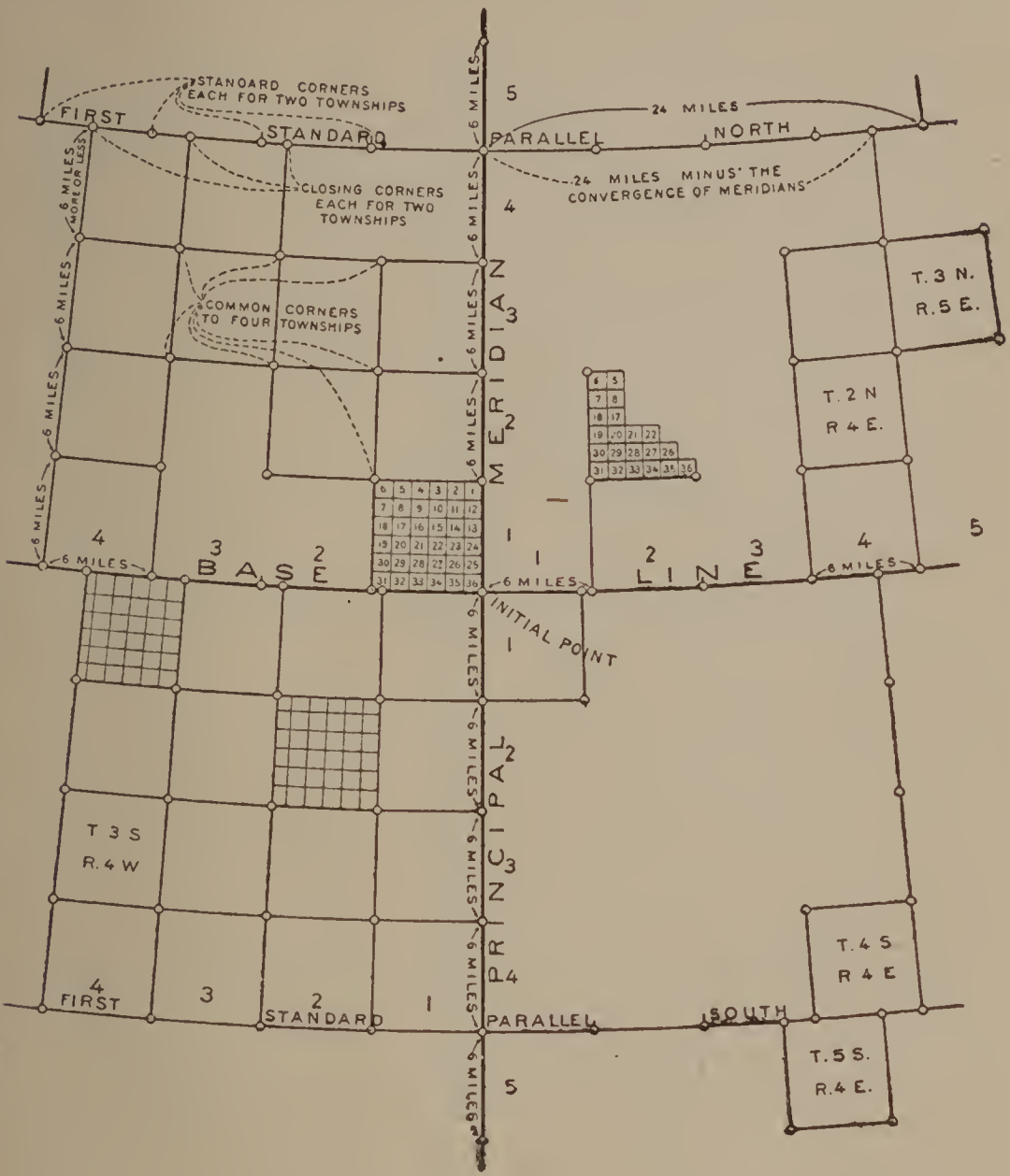


FIG. 7.—Rectangular system of Land Office surveys.

divided, quartered, quarter-quartered, etc. The unit of the system is the township, which is, conventionally,

6 miles square and contains 36 sections of 640 acres each, or 23,040 acres.

Inasmuch as meridian lines converge toward the north pole, it is evident that townships will have a trapezoidal form and that they will materially decrease in area toward the north unless correction lines are introduced. The system is as follows (see fig. 7, p. 37):

Beginning at the initial points, a base line is run due east and west with standard parallels 24 miles distant. From these parallels guide meridians, 24 miles distant, are run due north and "close" on the standard parallels. This divides the region into tracts 24 miles square, except for the convergence mentioned. Then township lines are run, making tracts which are 6 miles square. These are afterwards "subdivided" into sections. The conventional section is legally subdivided into quarters and quarter-quarters, and by common usage into smaller subdivisions, but unless otherwise specified these are all proportionate areas to the quarter section. A conventional section is cut into quarters by straight lines which connect the quarter corners on its boundaries.

Whenever, as in the case of timber sales, it becomes necessary to survey and mark a line which bounds some alienation it is important that the line should be either legally correct or should be agreed to in writing by the private owner for the purpose of the sale, and in case of a disagreement no timber should be marked for cutting in the disputed strip until the merits of the case have been submitted to the Forester and his instructions received.

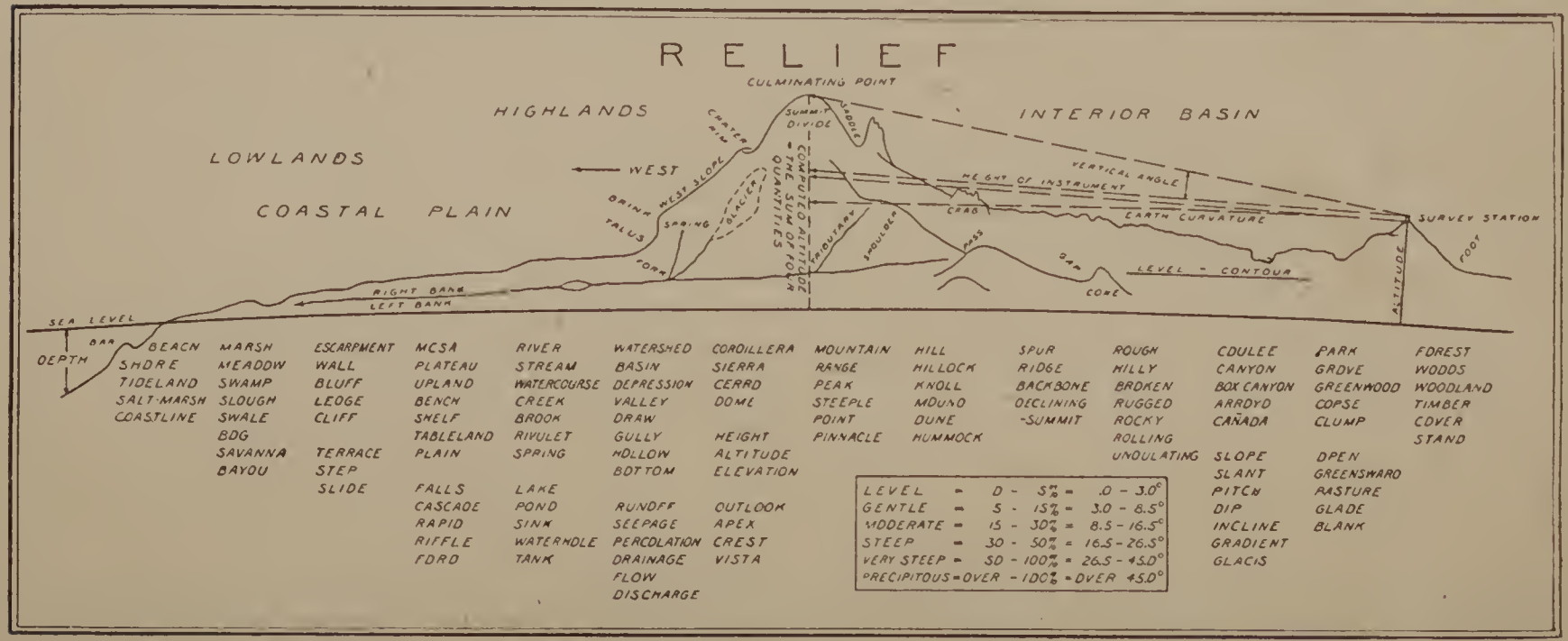


FIG. 8.—Names of physiographic features.

There are many exceptions to the simple rectangular scheme as outlined above, and many different anomalous townships and sections result from methods which have to be employed in special cases.

It is intended that skilled instructors in surveying and mapping shall visit the different National Forests as rapidly as possible and give practical help to all Forest officers who may be able to profit by the opportunity.

This pocket manual of instructions will, in this connection, serve as a primer in the course of study which will naturally follow. Any unusual problems which require solution may be referred to these instructors or to the office at Washington.

○